UNDERSTANDING LED LUMINAIRE LIFETIME AND RELIABILITY

7/17/2012

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A Conundrum…

- Wanted: A simple statement of product "life" for solid state lighting product
- Problem: The technology is too new to know just how and when it is likely to fail
  - Lumen depreciation has had a lot of press – but it's *not likely to be the determinant of product life*
  - Getting a good answer right now means measuring a lot of product for a long time – *impractical*
- Conclusion: *We don't have a good answer!*

DOE's 2010 Report*

- Lumen maintenance lifetime (LML) is when a specific fraction of product has fallen below a stated percent of initial total lumen output
  - L_{zz} represents a level of zz% of initial luminous flux
  - B_{xx} designates xx% of product has failed
  - So LML is specified, for example, as "L_{70}/B_{50}"
- *Many* failure modes can cause low light, not just the LEDs
- But verifying this number is almost always prohibitively expensive
  - Accelerated testing of full luminaires isn't practical either
  - A statistical model based on subcomponent and material data may be best

* *LED Luminaire Lifetime: Recommendations for Testing and Reporting*, May 2010

A Continuing Reliability Initiative

- An updated report was issued in June, 2011
  - Clarified that the loss of lumen output could be for *any reason*
  - Emphasized that LM-80 source data with TM-21 projection *is not a proxy for lifetime*
  - Provided options for interim specifications and for the treatment of color shift
- Established a new effort to work towards a statistical reliability model

This Used to be So Simple

LIGHT

NO LIGHT

Definitions - Failure

- "Failure" is an event which ends the useful life of a product
  - May need some definition if not evident, e.g. excessive lumen depreciation or color shift
  - May result from a design flaw, a manufacturing defect, or normal wear-out
  - May result from an interaction among otherwise long-lived components or materials

Definitions – Reliability

- Reliability is the ability of a product to perform its required functions for a *specific period of time*
  - Often reported as mean time between failures (MTBF)
  - Especially useful for repairable systems, as it determines the average maintenance interval

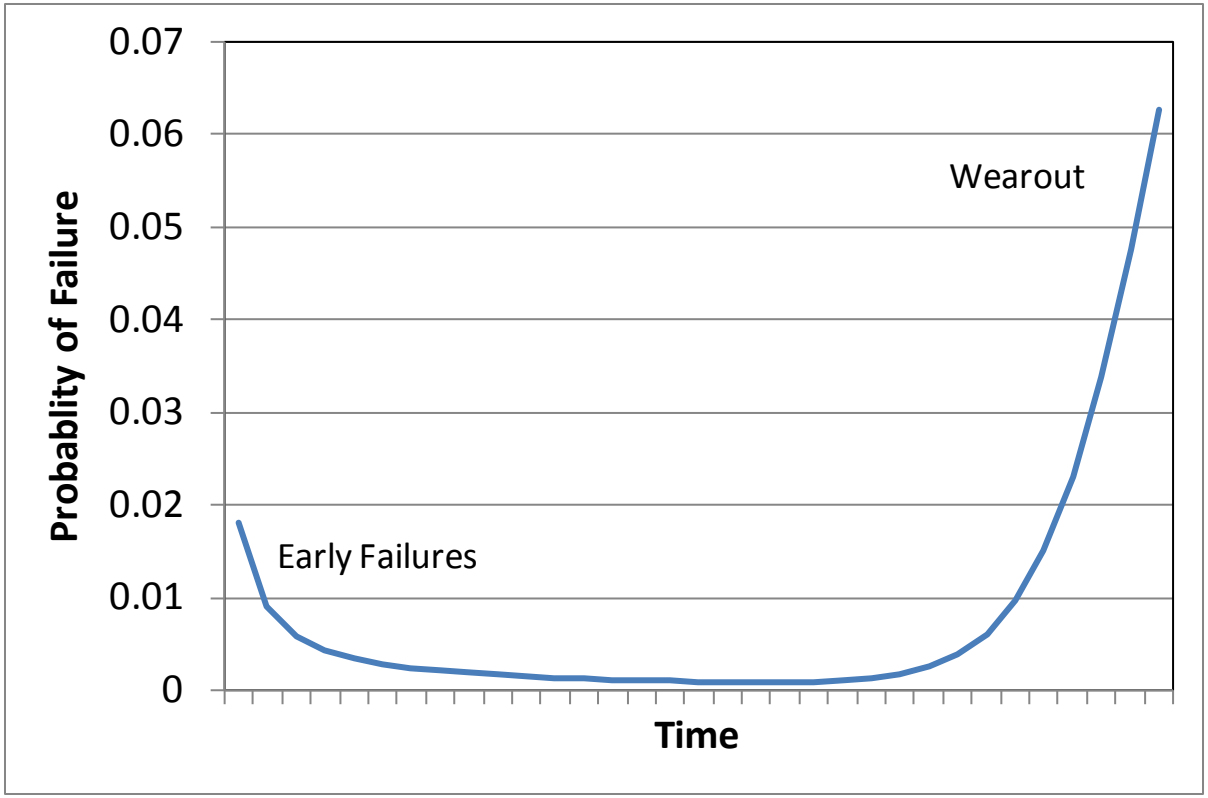
Definitions - Lifetime

- Lifetime is an estimate of how long a product is expected to operate as intended
  - Conventionally defined as “no light”
  - For LEDs, defined as “not enough light” (which might include no light) for ANY reason
  - NOT limited to lumen depreciation
  - Does not consider repair or replacement of parts
  - This definition does not include color shift, which we know is a problem for some applications

Typical Failure Behavior over Time

The "Bathtub" -

- High initial failure rate (infant mortality)
- Long period of low random failures
- Wear out period (end of life)



Distinguishing among failures

- Design flaws – less common than in the past
  - Poor thermal management is most common
  - Other less-common design issues
    - Overdriving the LEDs or otherwise poor driver design
    - Use of incompatible chemicals, moisture ingress, etc.
- Manufacturing defects will always be with us, but can be minimized (infant mortality)
- "End of life" represents "normal" behavior of a well-designed and made quality product
  - Usually involves several failure modes

Interim Recommendations for Color

Three categories, treated differently:

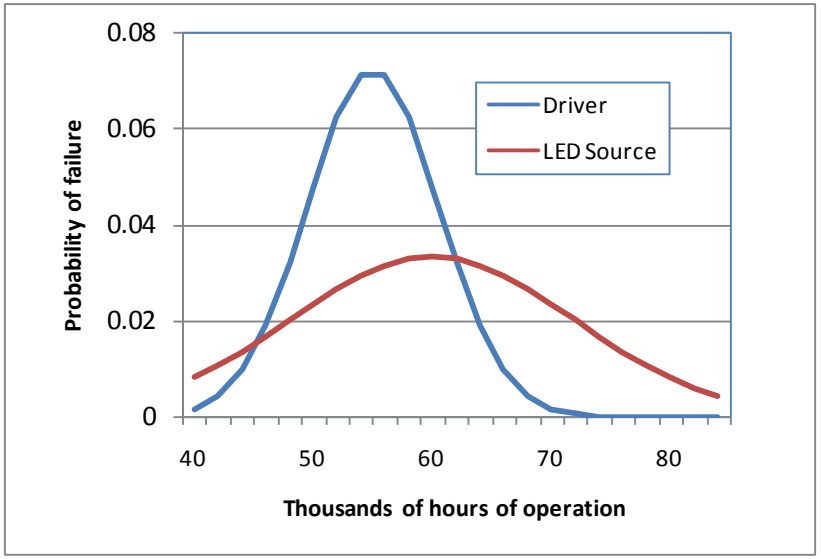
- Lamp replacements: Specify color in general terms for non-critical markets
- Standard grade luminaires: Specify maximum warranted color shift (CCT) and period of time (may be less than lifetime)
- Specification grade luminaires (and lamps): Maximum color shift over stated lumen lifetime should be provided

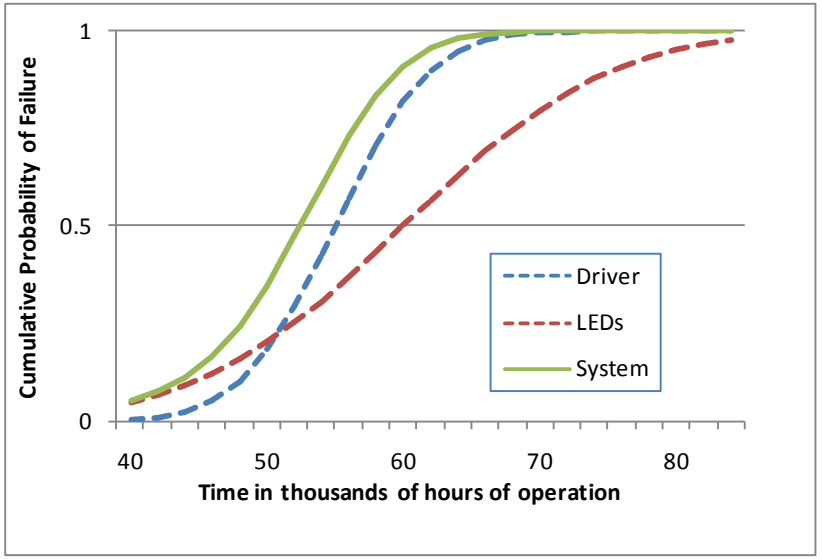
A Reliable, Quality Product Means…

- Overall design for reliability *appropriate to the application*
  - Longer life can help justify price premium, but it need not be "forever"
- Few initial (infant failures)
  - No inherent design flaws
  - High-quality manufacturing with few defects
- A low rate of random failure during normal life
- Relatively tight distribution of normal wear-out

Hypothetical Example

- Simplified 2-failure-mode “made up” system – Driver and LED Source
- Mean time to failure for driver is 55K hours and for LEDs 60K hours
- Joint system failure of half the product would be about 53K hours
- Key things to learn:
  - “Life” is a statistical measure
  - All failure modes can contribute, even if closely matched





Time Out for a Quiz…..

What should the Warranty Say?

- "60,000 hours"?
  - "60 years"?
- "53,000 hours"?
  - "48.4 years"?
  - "22.8 years"?
  - "35 years"?

A System Reliability Approach

- Testing full luminaires is time consuming and expensive; we need a better way
- Separate subcomponent reliability data could provide a basis for statistical system reliability design
  - Standardized reporting formats are needed
  - Protocols are needed to estimate system reliability using subcomponent data
- Accelerated methods for testing could help for both subcomponent statistics and for luminaire verification
- All of this requires an industry-wide cooperative effort, but the potential benefits are great

What Can I Do Right Now?

- Consider alternatives to truly verified lifetime:
  - Don't claim a lifetime; state a *warranty*
  - State the predicted source L_{70} but *don't call it "life"*
  - State the predicted depreciation *for a given time*
- Contribute to the development of a statistical model
  - Join the LED System Reliability Consortium
  - Contribute subcomponent and materials reliability data and field data to the effort
  - Don't encourage misrepresentations of "life"

Learn More

The second edition of the DOE/NGLIA working group recommendations

On the SSL website www.ssl.energy.gov